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THE UNIVERSITY OF ALBERTA

EVALUATION OF FULL FAT CANOLA SEED AS AN ENERGY SOURCE FOR YOUNG PIGS

by

(C) JAYNE ANNE SHAW

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

ANIMAL NUTRITION

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

FALL 1987

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(SIGNED) Jayne Shaw

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled EVALUATION OF FULL FAT CANOLA SEED AS AN ENERGY SOURCE FOR YOUNG PIGS submitted by JAYNE ANNE SHAW in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in ANIMAL NUTRITION.

Frank Pehrson

Supervisor

Date Aug. 21, 1987

ABSTRACT

Several experiments were conducted to determine the feeding value of full fat canola seed (CS) for weanling pigs. One hundred and thirty-two Landrace X Yorkshire pigs, weaned at 28 days of age, were fed ad libitum, a 20% crude protein starter diet containing either 0%, 7.5%, 15%, or 30% raw, ground or 'Jet-Sploded' canola seed (B. Campestris cv. tobin). There were no significant differences for average daily gain (ADG) or average daily feed intake (ADF) between the pigs fed 0%, 7.5% or 15%, raw ground CS or 'jet sploded' CS supplemented diets. Gain per unit of feed (GPF) was reduced ($P<0.05$) for pigs fed diets containing 7.5% and 15% 'jet-sploded' CS. For pigs fed diets containing 30% CS, either raw, ground or 'jet-sploded', ADG, ADF, and GPF were reduced ($P<0.01$) relative to that of pigs fed a control diet and other CS supplemented diets.

Digestibility coefficients for energy, protein, and dry matter for the complete diets were lower for the control diet than for the CS supplemented diets. There was no significant difference in performance between pigs fed diets containing 15% CS or 9% canola meal (CM) plus 6% canola oil or a control soybean meal (SBM) supplemented diet. In general, processing CS in a 'jet-sploder' over a wide range of temperatures did not improve its nutritive value. Digestibility coefficients were determined for energy, protein, and dry matter of CS and CM using an inert marker for ileal and fecal collection, mobile nylon bag technique (MNBT), and TME_n bioassay. The largest values for apparent digestible energy (ADE) were obtained using a fecal marker and the smallest values by were obtained by ileal collection with MNBT determined values being intermediate. TME_n values for a range of feeds, including CS, could be used to accurately predict ADE values for swine.

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I. INTRODUCTION

A. FEEDING FAT TO PIGS

In todays swine industry, with the increase in operating costs, sows are expected to have an improved reproductive performance and produce prodigious numbers of offspring with a high survivability. Pigs are being weaned earlier and feeder pigs reach market weight earlier on a smaller amount of feed than ever before. Because of these pressures to maximize production efficiency and because of a trend to reduced feed intakes in modern lean-type pigs, there has been a renewed interest in feeding fats and oils to pigs. In the U.K. there has been a three fold increase in the use of fats in swine diets during a period of almost static feed production (Freeman 1983).

Considerable research has been conducted to determine the benefits of adding fats to pig diets. For breeding sows, the addition of at least 8% fat to the diet during the last weeks of gestation can improve survival rate of baby pigs in herds where high mortality is a problem (Pettigrew 1981; Boyd 1978a; Seerley 1983). Fat supplementaion of the dam's diet increased plasma glucose concentration in the baby pig for 24 h. after birth (Boyd et al. 1978b; Seerley et al. 1974). These raised glucose concentrations may be indicative of increased liver glycogen concentrations (Seerley 1983). According to Seerley (1983) and Stahly (1983), adding fat to the diets of lactating sows will increase the quality and quantity of the milk, improve sow condition, reduce weaning to mating interval and increase the percent of sows returning to estrus within seven days of weaning.

When pigs are weaned from sows milk to dry feeds they experience a decreased nutrient intake resulting in a postweaning growth check (Leibbrandt et al. 1975a; Okai et al. 1976; Lecce et al. 1976). By increasing the energy density of the diet and improving the palatability of the starter pig diet, this growth check can be reduced (Campbell et al. 1975). Recently it has been shown, (Aherne et al. 1982) that the addition of 8-10% fat to the diet of pigs weaned at 3 or 5 weeks of age will significantly improve growth rate and feed conversion efficiency. Aherne et al. (1982) and Endres et al. (1985) suggested that the addition of 10%

lard to a starter diet having a constant nutrient to energy ratio, improved average daily gain and feed to gain ratio. Leibbrandt et al. (1975a) fed lard at 5% of the starter pig diet and also observed improved feed conversion efficiency. Cline et al. (1977) concluded that weanling pigs can utilize dietary fat to the same extent as glucose and lactose. Ether extract digestibility is also improved by adding fat to the diet of starter pigs (Leibbrandt et al. 1975b). Aherne et al. (1975) demonstrated that starter pigs fed a diet containing 15% fat consumed 25% less feed than pigs fed a non-fat control diet. This reduced feed intake resulted in a lowered protein intake. To compensate for reduced feed intake it is recommended to increase the protein content of the fat supplemented starter pig diets.

The addition of fats and oils to the diets of growing and finishing (20-100 kg) pigs will improve average daily gain and feed conversion efficiency (Wagner et al. 1963; Greeley et al. 1964; ARC 1981; Campbell et al. 1983; Stahly 1983). In hot weather the addition of fat to swine diets tends to stimulate the pig's voluntary feed intake. A possible explanation for this increased feed intake is that the metabolism of fat produces less "waste heat" than the metabolism of carbohydrates. Therefore a "hot" pig is able to eat more because it has less heat to dispose of (Stahly 1983).

Fats commonly used in animal feeds include tallow, lard and a mixture of both but the practise of adding fats to pig diets is limited due to the high cost of the fats. For farms with their own feed mixing systems, adding fat to the diets is difficult to do since fat is solid at room temperature and must be melted prior to inclusion in the rest of the diet. Eighty percent of diets fed to pigs in Alberta are mixed on the farm using proportioning mills. It is difficult to add fats or oils to diets processed by volumetric mills, especially in winter. In addition to these problems, fat supplemented diets "bridge" in bulk bins and feeders and when stored in bags they tend to "oil-out" (Pettigrew 1981). As the amount of fat added to the diet increases, the ease of pelleting decreases and a softer more crumbly pellet is produced (Pettigrew 1981). However there has been of late, considerable interest in adding fats to swine diets. One possible way of adding fat to swine diets processed through volumetric mills is by using full fat seeds. In Canada the full fat seed of choice is Canola seed (CS). When

ground with the barley through a hammermill or a volumetric mill, the CS is thoroughly ground, thus oil can be added to swine diets without any of the difficulties encountered when directly adding fats or oils to the diet.

B. FEEDING FULL FAT OILSEEDS

Full fat rapeseeds contain approximately 40% ether extract, 22% crude protein, and up to 24.5 MJ gross energy/kg (Robblee et al. 1983; Bayley et al. 1975). Unfortunately, rapeseed also contain glucosinolates that have been identified as a source of goitrogenic and growth depressing factors. Glucosinolates are compounds whose breakdown products cause growth and reproductive problems when fed to non-ruminant animals. Glucosinolates usually measured include 3-butenyl-, 4-pentenyl-, and 2-hydroxy-3-butenyl-glucosinolates (Appelqvist 1972). These glucosinolates are hydrolyzed by the enzyme myrosinase (β-thioglucosidases EC 3.2.3.1) (Bjorkman 1976) to produce glucose, sulphate, isothiocyanates, thiocyanates, nitriles, amines, and oxazolidinethiones (Kjaer 1976). The nature and amount of these various products depends on the nature of the glucosinolate present, the source of the myrosinase and the reaction conditions (Belzile et al. 1963; Paik et al. 1980; Bell 1980).

Feeding full fat rapeseeds to swine has been studied by several reseachers. Bowland (1971) fed 10% raw, ground rapeseed to growing pigs and detected a decrease ($P<0.05$) in feed intake, no change in growth rate but an improved feed conversion efficiency. When diets containing 10% rapeseed were fed to starter pigs, there was a significant decrease in growth rate but feed intake and feed conversion efficiency was not decreased (Bowland 1972). Bowland and Newell (1974) fed raw, ground low erucic acid rapeseed (LEAR) to growing pigs and detected no significant difference in average daily gain (ADG), average daily feed intake (ADF), or gain per unit of feed (GPF) at 10% inclusion level. Castell and Mallard (1974) fed LEAR rapeseed at 0%, 4%, 8%, and 12% to growing pigs and also did not detect significant differences between treatments for ADG, ADF, or GPF.

Plant breeders have developed low erucic acid and low glucosinolate cultivars of rapeseed. These double low cultivars are trade named canola seed (CS)in Canada. To qualify for this name, the seed must contain less than 3 mg/gm glucosinolates and the oil must contain less than 5% erucic acid (Slinger 1977). Although many studies have been conducted to determine the feeding value of rapeseed, there have been few studies conducted to determine the feeding value of CS for swine. Castell (1977) compared three LEAR cultivars of rapeseed to one low erucic and low glucosinolate CS (cv tower), at the 10% inclusion level, to the diet of growing pigs and reported that pigs fed the tower supplemented diet had significantly superior growth rates. They suggested that CS fed at levels of up to 15% of the diet is unlikely to be detrimental to growing pigs. Castell and Falk (1980) also fed CS to grower pigs at increasing levels up to 15% and observed no significant differences in growth rate or feed intake but a significant improvement in GPF was noted at the 15% inclusion level of CS. Studies conducted by Bell (1984) to determine the nutritive value of frost-damaged CS for growing pigs, indicated that pigs fed 30% frosted CS in their diet had decreased ADG and ADF but that GPF was enhanced. There is a dearth of information on the feeding value of CS for weanling pigs. Salo (1980) fed CS to weanling pigs at 0% and 10% of the diet and observed no significant difference in gain, feed intake or feed conversion efficiency. There was a trend, however, towards a decreased feed efficiency when 10% CS was included in the diet.

Although the glucosinolate levels in the CS being used today are very low, the glucosinolates present in unheated CS would still be hydrolyzed by the myrosinase present and the breakdown products would tend to reduce pig performance when CS was included in the diet. Grinding and pelleting CS supplemented diets does not inactivate the enzyme myrosinase, and may promote glucosinolate hydrolysis by increasing the degree of contact between the myrosinase and the glucosinolates (Carpenter 1960; Bell 1980). It is likely that further methods of processing such as heating would be more effective in destroying myrosinase and thus may improve the feeding value of CS (Carpenter 1960; Bell 1980).

Processing methods that have been used to improve the nutritive value of full fat rapeseed for swine are: addition of organic acid (Bowland et al. 1974); heat treating (Ochetim et al. 1980); extrusion (Bayley et al. 1975, and Ochetim et al. 1980); and infrared, microwave, and hot air treatment where the seed was heated for 24 h at 105°C in a hot-air oven (Eyre et al. 1984). The results of these studies show that treating the seed did not improve the nutritive value of the CS.

Another method used to process full fat CS is 'Jet-Sploding'™. The 'jet-sploder' subjects the seed to super heated air, for a set period of time. The seed is then passed through a roller mill (Morrill 1984). Processing seeds in this manner destroys antinutritional factors present, such as the byproducts of glucosinolate hydrolysis (Morrell 1984). "Jet-sploding' may also increase the digestibility of the oil in the seed and increase CS palatability (Morrill 1984).

C. AVAILABILITY OF FULL FAT CANOLA SEED

In 1982 early frost resulted in intensive damage to the canola crop in the prairies and nearly 50% of the crop was graded No.3 Canada or Canada Sample grade. Dockage rates were high and alternative uses for the damaged seed were sought (Bell 1984). In any given year up to 30% of the canola crop could suffer various degrees of frost damage (Bell 1984). Similar estimates for Alberta are that 9% to 18% of the Canola crop was damaged (Grade #3) over the last six years (Crop Statistics, Alberta Agriculture). The grain inspection division estimates that 83% of the 1984 rapeseed delivered to primary elevators qualified for grade No. 1 Canada and approximately 7% graded No. 3 Canada or lower (Canadian Grain Commission 1984). Oil from frost damaged canola seed is unsuitable for human consumption because the seed stops maturing at the point of frosting and leaves the oil high in chlorophyll which imparts a green colour to the oil (Slinger 1977).

Mills et al. (1984) studied the storability of frost-damaged canola and concluded that some heating and spoilage may occur during the first weeks of storage but can be prevented by ordinary careful management and aeration.

D. DIGESTIBILITY DETERMINATIONS

There are various methods used to determine the apparent digestible energy (ADE) value of a feedstuff or a diet. One method of determination is to add an inert marker to the feed in a known quantity relative to the nutrient content and examine the feces for the ratio of marker to nutrient remaining. The change in ratio indicates the apparant digestibility of the nutrient. Such markers include Cromium Oxide (Fenton and Fenton 1979), Acid Insoluble Ash (Furuichi & Takahashi 1981; McCarthy et al 1974), and Dysprosium (Kennelly et al 1980).

Conventional methods of determining the apparent digestible energy (ADE) value of a feed involve total feces collection (Bayley et al 1975; Robinson 1965). This method is time consuming and costly and does not take into account any associative effects of the other feed ingredients in the diet. In recent years the mobile nylon bag technique (MNBT) has been used to determine protein (Sauer et al. 1983a,b), energy and dry matter digestibilities (Sauer et al. 1984a,b). The MNBT can be used for the rapid measurement of the digestibility of feeds that would not be eaten singly by pigs because of palatability. Using MNBT, many different feed ingredients can be simultaneously tested and very little sample is required.

The determination of True Metabolizable Energy (TME_n) system in poultry may also be of help in determining the ADE value of feed for pigs. Sibbald et al (1983) demonstrated that there was a good correlation between the ADE of a feedstuff for a pig and from the TME_n value as obtained from adult cockerels. Using the precision feeding proceedure as described by Sibbald et al (1976; 1982; 1985), by starving and force feeding birds a known quantity of a feed ingredient, the TME_n of that ingredient can be determined from quantitative collection of the feces over a 48 hour period (Sibbald et al. 1976).

If this system indeed allows for an estimate of the ADE values of a feedstuff for the pig, then much time and money can be saved in determining the ADE value of feedstuffs and diets fed to pigs.

The objectives of these studies were to evaluate the nutritive value of CS for young pigs, to determine the ADE value of CS using ileal and fecal inert marker methods and the

MNBT, and to determine the relationship between the TME_n and ADE values of a variety of feedstuffs including CS.

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II. AN EVALUATION OF THE FEEDING VALUE OF FULL FAT CANOLA SEED FOR WEANLING PIGS

A. INTRODUCTION

The abrupt change experienced by the pig at weaning, from an all milk diet to a dry solid feed, invariably results in a reduced nutrient intake for a few days after weaning. This reduced feed intake results in a postweaning growth check (Leibbrandt et al. 1975b; Okai et al. 1976; Lecce et al. 1976). It has been frequently demonstrated that increasing the energy density of the diet and/or improving the palatability of the starter pig diet by the inclusion of fat, reduces this growth check (Campbell et al. 1975; Speer 1976). During the last few decades there have been many experiments conducted to study the effect of fat in the diet on growth rate (Leibbrandt et al. 1975a) and feed conversion efficiency during the starter period (Allee et al. 1972). Aherne et al. (1982) and Endres et al. (1985) suggested that the addition of 10% lard to a starter diet with a constant nutrient to energy ratio, improved average daily gain and feed to gain ratio. Leibbrandt et al. (1975a) fed lard at 5% of the starter pig diet and also reported improved gain per unit of feed. Cline et al. (1977) concluded that piglets can utilize high levels of dietary fat to the same extent as glucose and lactose. However, feed intake is also affected by the addition of fat in the starter pig diet. Aherne et al. (1975) reported that pigs fed a diet containing 15% oil consumed 25% less feed than pigs fed a control diet without oil supplementation. This reduced feed intake resulted in a lowered nutrient intake. Therefore, it is usually recommended that the nutrient content of fat or oil supplemented diets be increased to compensate for the expected reduction in feed intake.

Fats used in animal feeds include tallow, lard and a mixture of both, but the practise of adding fats to starter pig diets is limited due to the high cost of fats. For farmers with their own feed-mixing system, adding fat to the pig diets is difficult because fat is solid at room temperature and must be melted prior to inclusion in the diet. High fat diets "bridge" in bulk bins and feeders and when high fat rations are stored in bags they tend to "oil-out" (Pettigrew 1981). As the amount of fat added to the diet increases, the difficulty of pelleting

increases and a softer more crumbly pellet is produced (Pettigrew 1981).

The feeding of full fat rapeseed is another method of increasing the energy density of the diet. Full fat rapeseed contain 42% ether extract, approximately 22% crude protein, and up to 24.5 MJ gross energy/kg (Robblee et al. 1983). Unfortunately, full fat rapeseed contain glucosinolates that can be hydrolyzed by the enzyme myrosinase, to form goitrogenic compounds such as oxazolidinethione and isothiocyanates (Belzile et al. 1963; Bell 1984b; Paik et al. 1980). Cultivars of rapeseed have been developed which contain very low levels of erucic acid and glucosinolates. These double low cultivars of rapeseed carry the trade name Canola seed (CS). To qualify for this name, the seed must contain less than 3 mg/gm glucosinolates and the oil must contain less than 5% erucic acid (Slinger 1977). Whether or not the nutritive value of CS can be improved for weanling pigs has not been determined. One method of heat treating CS is that of 'jet-sploding'. In this process the CS is exposed to dry heat for a very short period of time. A full description of this process is presented in Appendix 2.

The primary objective of this study was to determine the nutritive value of CS for weanling pigs.

B. MATERIALS AND METHODS

General Methods

All diets were formulated to meet or exceed NRC (1979) nutrient requirements for swine. The diets were steam pelleted. Feed and water were available ad libitum. The environmental temperature was maintained at 25°C throughout the four week trial. Pigs were weaned at 28 days of age and were housed individually in either 1.2m x 1.2m or 1.2m x 0.6m tenderfoot floor pens. Feed intake and pig weights were recorded weekly.

Experiment 1

Sixty-eight crossbred (Yorkshire X Landrace) pigs (ave. wt. 7.9kg), were allotted to one of four dietary treatments shown in Table II.1. The control diet contained 20% crude

protein and was based on wheat, barley, soybean meal (SBM), and 2% added fat. In diet 2 SBM, wheat and fat were replaced by 7.5% raw full-fat canola seed. Diet 3 was similar to diet 2 but contained 7.5% 'jet-sploded' canola seed and diet 4 contained 15% 'jet-sploded' canola seed. The diets were formulated to be isonitrogenous and isoenergetic on a gross energy basis.

The canola seed fed in this experiment was 'jet-sploded' for 60 to 90 seconds upon the recommendation of the staff at the California Pellet Mill and the seed reached an estimated seed temperature of 260°C.

Experiment 2

From the results of experiment 1 it was concluded that the poor performance of the pigs fed the diets containing the 'jet-sploded' CS was a consequence of too high a temperature being used during the 'jet-sploding' process. The objective of this experiment, therefore, was to determine the optimum temperature for the 'jet-sploding' technique that would deactivate the enzyme myrosinase but not damage the lysine in the protein.

To determine the optimum temperature at which to 'jet-splode' CS, 100 kg of CS (B. Campestris cv. tobin) was divided into ten, 10 kg lots. Each 10 kg was 'jet-sploded' for a particular period of time ranging from 22 to 51 secs. The combinations of time and temperature used are presented in Table II.2. The CS was allowed to cool at room temperature overnight. One sample of the previously 'jet-sploded' CS and one sample of the raw ground CS were included in the data set.

Digestibility coefficients for energy, crude protein, and dry matter were determined by the mobile nylon bag technique (MNBT) (Appendix 1) as described by Sauer et al. (1983 a,b). The availability of lysine was determined for the 12 CS samples using Carpenter's test as modified by Booth (1971). Samples of the 12 processed sets of seed were analysed for total glucosinolate levels and myrosinase activity using the method of Daun and McGregor (1981).

Experiment 3

In experiment 1 pigs fed 7.5% raw, ground CS performed as well as pigs fed the control diet. The objective of this experiment was to determine the performance of pigs fed diets containing 15% raw CS or the equivalent amount of canola meal (CM) and canola oil contributed by 15% CS,(9% CM, 6 % oil) or a diet containing soybean meal (SBM) and canola oil.

Thirty crossbred pigs weaned at 28 days of age (ave. wt. 7.5 kg), were allotted to one of the three diets shown in Table II.3. Diet 1 was a 20% crude protein starter diet based on SBM, oat groats, cornstarch, and wheat. In diet 2, cornstarch was removed and 32% of the SBM was replaced by 15% raw, ground CS. Diet 3 was similar to diet 2 expect that it contained 9% canola seed and 6% canola oil. All diets were formulated to be isonitrogenous and isoenergetic.

Experiment 4

Sixty-five crossbred pigs, weaned at 28 days of age (ave. wt. 7.8 kg), were allotted to one of the five diets shown in Table II.4. Diet 1 was formulated to contain 20% crude protein based on SBM and canola oil; Diet 2 contained 15% raw, ground CS; Diet 3 contained 15% 'jet-sploded' CS; Diet 4 contained 30% raw, ground CS; and, Diet 5 contained 30% 'jet-sploded' CS. From the results of experiment 2, the recommended temperature for processing the CS was 116°C.

To each of the five diets the inert marker, Dysprosium Chloride, was incorporated at a concentration at 10 ppm elemental Dysprosium. Fecal grab samples from each pig were collected, in the morning, on days 7, 8, and 9 of the feeding trial then freeze-dried, and ground. The 3 day samples were pooled by weight and mixed thoroughly. Feed and fecal samples were analyzed for dry matter and total Kjeldahl nitrogen using the techniques outlined by AOAC (1980), and gross energy of combustion as described by Harris (1970). Dysprosium concentrations in feed and feces were determined using instrumental neutron activation analysis (INAA) at the SLOWPOKE reactor, University of Alberta, following the

proceedure of Kennelly et al. (1980). Digestibility coefficients for dry matter, crude protein, and energy were calculated for each diet.

Costs for each ration used in experiment 4 were calculated and are presented in Table II.4.

Statistics

The results of experiments 1, 3, and 4 were statistically analyzed by ANOVA as described by Steele and Torrie (1980). Where appropriate the treatment means were subjected to a Student-Neuman-Keuls multiple means comparison test at the $P<0.05$ level, (Steele and Torrie 1980).

Regression analysis was performed on mean data from experiment 2, to determine if a relationship existed between the temperature of the CS during processing and the digestibility coefficients for crude protein, energy, and dry matter or the availability of lysine. Cook's distances (Draper and Smith 1981) were also calculated. This latter statistical method uses simultaneous regressions on the data to detect influential observations. If one observation artifically influences the primary regression, it allows one to legitimately remove that data point. In this case it was used to determine whether the data generated from the room temperature sample of the CS and the extremely hot sample of CS could be included in computation of the regression equations (Draper and Smith 1981).

C. RESULTS

Experiment 1

One gilt became ill during the experiment and was removed from the trial.

The results of experiment 1 are presented in Table II.5. There was no significant difference between the pigs fed the four diets for average daily gain (ADG), or average daily feed intake (ADF). For gain per feed (GPF) there were differences ($P<0.05$) between means for the four treatment groups. Results of the Student-Neuman-Keuls test showed that pigs

fed the two diets containing the 'jet-sploded' CS, were significantly poorer in GPF than pigs fed the other two diets.

Experiment 2

Digestibility coefficients and lysine availability of the 12 heat treated samples of CS are presented in Table II.6. As a result of the Cook's distance test, it was concluded that the digestibility coefficients and the lysine availability values for samples kept at room temperature or heated to 260°C did not artificially influence the regression analysis and were, as such, included in the analysis. Regression analysis showed that the digestibility coefficients for crude protein, energy, and dry matter, were not influenced by the temperature of the processing. The availability of lysine, however, decreased significantly as the temperature of the seed increased. The regression equation was: $Y=6.503+-.0025X$, where Y= the lysine availability and X= the temperature of the process in degrees C. The correlation coefficient is $r=.553(P<.10)$ (Figure II.2.).

Results from the glucosinolate and myrosinase enzyme assays are presented in Table II.7. The results indicate that the myrosinase enzyme activity was reduced to nearly zero percent in all 'jet-sploded' samples. At the least severe processing temperature (116°C) no myrosinase enzyme activity was detected. Total glucosinolate levels were not decreased significantly until the CS was treated at the higher temperatures (182°C and 260°C), at which temperature total glucosinolate levels were reduced by approximately 20%.

Experiment 3

The results of Experiment 3 are presented in Table II.8. There were no significant differences for ADG, ADF, or GPF of pigs fed the diets containing 15% CS, 9% canola meal and 6% canola oil or SBM and canola oil. There was, however, a trend towards a decrease in ADG and ADF for the pigs fed the 15% CS diet.

Experiment 4

The results of experiment 4 are presented in Tables II.9, II.10, and II.11. Pigs fed diets containing 30% CS had significantly lower ADG ($P<0.05$), ADF and GPF ($P<0.01$) than pigs fed the control or 15% CS supplemented diet. Processing methods (raw, ground or 'jet-sploded') did not significantly improve ADG, ADF, or GPF.

The pooled data for pigs fed diets containing 15% or 30% CS irrespective of processing, are shown in Table II.10. Performance of pigs fed the 30% CS diets was significantly lower than that of pigs fed diets containing 15% CS. The pooled data in table II.11 shows that 'jet-sploding' did not significantly improve the nutritive value of CS for pigs.

Digestibility coefficients for protein, energy and dry matter for the five dietary treatments are presented in Table II.12. Pigs fed the control diet had lower ($P<0.05$) dry matter, protein, and energy digestibility coefficients than those fed the other four diets containing CS either processed or raw. The gross energy content and energy digestibility was slightly but not significantly reduced for pigs fed the 30% 'jet-sploded' diet compared with the 30% raw, ground CS diet.

D. DISCUSSION

Because ADG and ADF were not significantly different between treatment groups in experiment 1, it may be concluded that the growth depressing factors in the raw, ground CS were not at high enough levels in the diet to affect the growth rate or GPF of weanling pigs when CS was included at 7.5% of the diet. The pigs fed the diets containing the 'jet-sploded' seed did not perform as well as those fed the control diet or the diet containing 7.5% raw CS. This may be because the 'jet-sploding' process was too hot and reduced the lysine digestibility in the CS (Finlayson 1966; Lo and Hill 1972; and Girault 1973). Bell (1980) concluded that cooking CS, containing 8% moisture, for 10-15 minutes at 100°C was sufficient to denature the myrosinase enzyme, and that heating CS for longer periods of time or a higher temperature than 100°C may decrease the availability of amino acids, especially lysine.

In experiment 2, CS processed at the highest temperature (260°C) had similar digestibility coefficients for crude protein (CP), energy (E) and dry matter (DM) as CS processed at lower temperatures. No pattern emerged across the array of samples in regard to these digestibility coefficients. However, the lysine availability decreased as the temperature of processing increased, indicating a possible binding of the amino acid.

Because the inclusion of 7.5% CS in the diets in experiment 1 did not significantly reduce pig performance, it was deceided to evaluate the effects of adding 15% CS to the diets of starter pigs. Studies conducted by McIntosh and Baidoo (1985), McKinnon and Bowland (1977), and Castell (1977) indicated that feeding a level of 9% canola meal to starter pigs significantly reduced performance. Since CS contains 60% meal and 40% oil, this would mean that at a 15% CS level of inclusion the diet would contain 9% meal and 6% oil and a decrease in pig performace would be anticipated. However, the results of experiment 3 did not substantiate the conclusion that feeding 9% canola meal (CM) significantly reduces pig performance when compared with the pigs fed the other two diets. The growth rate of the pigs fed 15% raw, ground CS, although not significantly different, was slightly reduced. These pigs also consumed less, resulting in a GPF similar to the pigs fed the diet containing the CM and oil and the SBM and oil diet. These results are in agreement with those of Bell (1984a) who reported no significant difference in ADG or GPF when frozen full fat CS was included in the diets of growing pigs at levels of 0%, 10% and 20%. Castell et al. (1974) also detected no significant difference in growth parameters between pigs fed diets containing 0% or 12% Span rapeseed (a low erucic acid cultivar) for grower pigs. When testing Torch (a double low cultivar of canola seed) at 15% inclusion rate, Castell et al. (1977) observed no significant difference in ADG, ADF, and FCE compared with pigs fed a diet containing no CS. Their explanation for the equal performance of the pigs fed 15% CS and those fed the control diet was that growth is unlikely to be reduced if nutrient supplies are maintained within recommended levels. Castell et al. (1980) fed diets containing Candle (a double low cultivar of canola seed) at 15% inclusion rate to grower pigs and observed no significant effect on GPF compared with pigs fed a control diet. Salo (1980) fed CS to weanling pigs at 0% and

10% of the diet and reported no significant differences in growth rate, feed intake or GPF. However, there was a trend towards reduced GPF for pigs fed the diet containing 10% CS.

Because no significant differences were detected in the performance of pigs fed 15% raw, ground CS over the control diet, the amount of CS supplemented in the diet was increased to 30% in experiment 4. A reduction in pig performance was expected when CS was included at 30% of the diet, therefore, CS 'jet-sploded' at the coolest temperature (116°C) was evaluated to determine if processing improves the quality of the CS diet beyond that of the control diet. In experiment 4 increasing the level of CS in the diets of starter pigs to 30%, reduced ($P<0.05$) growth rate, feed intake and the GPF. The 'jet-sploding' of CS did not improve pig performance when CS was included at 15% or 30% of the diet. Digestibility coefficients for protein, energy, and dry matter were highest for diets containing 30% CS, possibly a consequence of its increased oil content. The addition of fat to starter pig diets has generally improved ether extract digestibility (Leibbrandt 1975b). However, in this experiment the digestibility coefficient for protein, energy and dry matter were generally improved at 30% CS supplementation. This improved digestibility did not compensate for the large decrease in feed intake. The reduced feed intake of pigs fed CM supplemented diets has been previously reported and is most likely due to the reduced palatability of such diets (Baidoo et al. 1986).

In view of the lack of difference between the performance of the pigs fed the raw, ground CS and the 'jet-sploded' CS at all inclusion levels and the fact that at 15% CS in the diet did not improve pig performance relative to the pigs fed the unsupplemented control diet, the cost factor of each diet becomes important. Comparing the cost per kg of the diets, the CS supplemented diets were less expensive than the control diet due, primarily, to the cost of the fat addition and the high inclusion rate of SBM in the control diet. The raw, ground CS supplemented diets were also less expensive than the 'jet-sploded' CS diets due to the processing cost of approximately $8.00/tonne (California Pellet Mill, personal communication).

E. SUMMARY

Including canola seed in weanling pig diets at levels of 7.5% or 15% had no significant effect on average daily gain, average daily feed intake or gain per unit of feed. A decrease in pig performance was observed when CS was included at 30% of the diet. CS may have considerable potential as an energy source when conveniently added to swine diets at 15%.

The 'Jet-Sploding' process did not improve the nutritive value of the CS for young pigs and cost per unit of gain was lowest for pigs fed CS supplemented diet at the 15% raw CS level. The CS used in this study was graded No. 1. Canada. Savings per kg of diet would be increased if less expensive CS were supplemented in the diet.

Table II.1. Formulation and composition of diets. (Exp. 1.)

Treatments	1 Control	2 7.5% raw canola seed	3 7.5% Jet-sploded canola seed	4 15% Jet-sploded canola seed
Ingredients, as fed				
Wheat	43.5	39.8	39.8	34.8
Barley	5.0	5.0	5.0	5.0
Oat groats	25.0	25.0	25.0	25.0
Soybean meal (44%)	17.6	15.8	15.8	13.3
Fish meal (63%)	2.0	2.0	2.0	2.0
Dried whey	1.5	1.5	1.5	1.5
Mixed fat	2.0	—	—	—
Canola seed, sploded	—	—	7.5	15.0
Canola seed, raw, ground	—	7.5	—	—
Iodized salt	0.4	0.4	0.4	0.4
Gr. limestone	1.0	1.0	1.0	1.0
Ca. phosphate	1.0	1.0	1.0	1.0
Vit-Min. premix†	1.0	1.0	1.0	1.0
Chemical analysis, as fed				
Dry matter, %	86.9	86.1	87.4	87.9
Crude protein, %	20.0	19.8	20.2	19.8
Gross energy, $MJ.kg^{-1}$	17.1	17.1	17.5	17.9
Ether extract, %	5.6	6.7	6.3	9.0
Lysine, %	1.2	1.3	1.2	1.2

†Premix - each kg of diet contained: 5,000 IU Vitamin A, 500 IU Vitamin D_3, 22 IU Vitamin E, 12 mg Riboflavin, 45 mg Niacin, 25 mg Ca. Pantothenate, 30 μg Vitamin B_{12}, 500 mg Choline Chloride, 20 mg Zn, 12 mg Cu, 150 mg Fe, 12 mg Mn, 20 mg Biotin, 0.3 mg Selenium, 2.5 g ASP 250, 2.5 g Lysine.

Table II.2 Processing regime for full fat canola seed (Exp. 2.)

Approx. seed temperature (°C)	Time (sec.) in chamber
116	22
121	23
127	26
132	30
138	35
149	36
154	38
160	41
171	49
182	51
260	90

Table II.3 Formulation and composition of diets (Exp. 3.)

	1 Soybean meal + oil	2 15% raw canola seed	3 6% oil 9% canola meal
Ingredient, as fed			
Wheat	20.00	21.00	21.00
Barley	8.00	9.00	9.00
Oat groats	23.00	23.00	23.00
Whey	10.00	10.00	10.00
Cornstarch	6.00	—	—
Soybean meal (44%)	26.00	18.00	18.00
Canola oil	3.00	—	6.00
Canola meal	—	—	9.00
Canola seed	—	15.00	—
Iodized salt	0.4	0.4	0.4
Gr. limestone	0.9	0.9	0.9
Ca. Phosphate	1.2	1.2	1.2
Vit-min. premix†	1.5	1.5	1.5
Chemical analysis, as fed			
Dry matter, %	91.60	92.00	92.70
Crude protein, %	20.06	19.94	19.89
Energy, $MJ.kg^{-1}$	16.9	17.5	17.9
Ether extract, %	4.4	7.8	8.0
Lysine, %	1.4	1.3	1.4

†Premix - each kg of diet contained: 5,000 IU Vitamin A, 500 IU Vitamin D_3, 22 IU Vitamin E, 12 mg Riboflavin, 45 mg Niacin, 25 mg Ca. Pantothenate, 30 μg Vitamin B_{12}, 500 mg Choline Chloride, 120 mg Zn, 12 mg Cu, 150 mg Fe, 12 mg Mn, 0.3 mg Selenium, 20 mg Biotin, 2.5 g ASP 250, 2.5 g Lysine.

Table II.4. Formulation and composition of diets. (Exp. 4.)

Treatments	1 Control	2 15% raw canola seed	3 15% Jet-sploded canola seed	4 30% raw canola seed	5 30% Jet-sploded canola seed
Ingredients, as fed					
Wheat	18.5	18.5	18.5	15.5	15.5
Barley	7.0	8.5	8.5	6.0	6.0
Oat groats	20.5	20.5	20.5	14.0	14.0
Dried whey	10.0	10.0	10.0	10.0	10.0
Cornstarch	5.0	—	—	—	—
Soybean meal	31.0	23.5	23.5	20.5	20.5
Canola oil	4.0	—	—	—	—
Canola seed, raw, ground	—	15.0	—	30.0	—
Canola seed, Sploded	—	—	15.0	—	30.0
Iodized salt	0.4	0.4	0.4	0.4	0.4
Gr. limestone	0.9	0.9	0.9	0.9	0.9
Ca. phosphate	1.2	1.2	1.2	1.2	1.2
Vit-min. premix†	1.5	1.5	1.5	1.5	1.5
Chemical analysis, as fed					
Dry matter, %	91.6	91.0	91.9	93.7	92.7
Crude protein, %	20.3	20.1	20.3	19.9	20.0
Gross energy, $MJ.kg^{-1}$	16.8	17.4	17.8	19.2	18.6
Ether extract, %	5.9	7.9	8.1	13.0	13.3
Cost of diets, ¢.kg^{-1} (incl. processing)	33.1	24.8	24.9	24.5	24.6

†Premix - each kg of diet contained: 5,000 IU Vitamin A, 500 IU Vitamin D_3, 22 IU Vitamin E, 12 mg Riboflavin, 45 mg Niacin, 25 mg Ca. Pantothenate, 30 μg Vitamin B_{12}, 500 mg Choline Chloride, 20 mg Zn, 12 mg, 150 mg Fe, 12 mg Mn, 20 mg Biotin, 0.3 mg Selenium, 2.5 g ASP 250, 2.5 g Lysine.

Table II.5. The effects of canola seed on pig performance. (Exp.1.)

Treatment	1 Control	2 7.5% raw canola seed	3 7.5% Jet-sploded canola seed	4 15% Jet-sploded canola seed	SEM	Sig.
Weight gain.d^{-1}, g	436	462	423	423	16.0	NS
Feed.d^{-1}, g	665	704	668	678	23.0	NS
Gain per feed	0.657^{a}	0.656^{a}	0.633^{b}	0.621^{b}	0.009	*

n = 16.
^{a,b}Means with the same superscript are not significantly different.
NS = not significant, * = significantly different ($P<0.05$).

Table II.6. Digestibility coefficients for 12 heat treated samples of canola seed.

Treatment	Crude protein %	Energy %	Dry matter %	Available lysine, % of protein
Raw, ground	75.7	65.82	62.20	6.36
116°C	71.5	64.90	60.66	5.80
121°C	70.4	62.42	57.46	6.18
127°C	85.3	61.03	55.70	5.63
132°C	73.9	63.67	60.72	6.00
138°C	71.4	58.36	54.98	5.89
149°C	74.3	61.21	57.90	6.01
154°C	72.2	49.33	47.44	5.68
160°C	73.5	60.28	57.00	5.95
171°C	78.0	60.00	57.34	5.58
182°C	78.2	69.26	66.70	4.58
260°C	72.5	54.20	52.64	5.57

Table II.7 Total glucosinolates and myrosinase enzyme activity in 12 'jet-sploded' full fat canola seed samples.

Processing† temperature (°C)	Total glucosinolates (mg/g) oil-free meal	Myrosinase activity (% of raw)
Raw	2.68	100.00
116	2.66	0.00
121	2.97	0.50
127	2.66	0.00
132	2.76	0.00
138	2.90	0.10
149	2.74	0.00
154	2.63	0.45
160	2.66	0.25
171	2.59	0.00
182	1.98	0.15
260	2.01	0.00

†Canola seed core temperature after "Jet-sploding".

Table II.8. The effects of canola seed on pig performance. (Exp. 3.)

Treatment	1 Control	2 15% raw canola seed	3 9% canola meal, 6% oil	SEM	Sig.
Weiht gain.d^{-1}, g	483	457	477	18.6	NS
Feed.d^{-1}, g	651	619	645	44.0	NS
Gain per feed	0.74	0.74	0.74	0.010	NS

n=10.
NS = not significant.

Table II.9. The effect of 0%, 15% and 30% raw, ground canola seed or 'jet-sploded' canola seed on pig performance.(Exp.4.)

Treatment	1 Control	2 15% raw, ground canola seed	3 15% Jet-sploded canola seed	4 30% raw, ground canola seed	5 30% Jet-sploded canola seed	SEM	Sig.
Weight gain.d^{-1}, g	498.0^{a}	512.2^{a}	476.5^{a}	414.9^{b}	408.0^{b}	14.4	••
Feed.d^{-1}, g	638.0^{a}	649.2^{a}	615.6^{a}	507.0^{b}	507.2^{b}	17.4	••
Gain per feed	.779^{b}	.791^{ab}	.774^{b}	.822^{a}	.802^{ab}	0.01	•

n = 13.
a,b Means with the same superscripts are not significantly different.
••Significant ($P<0.01$); •Significant ($P<0.05$).

Table II.10 Pig performance at two levels of canola seed, irrespective of processing (Exp. 4)

	Level of full fat canola seed			
	15%	30%	SEM	Sig.
Weight gain.d^{-1}, g	494	410	10.6	•
Feed.d^{-1}, g	623	505	12.8	••
Gain per feed	.783	.813	0.007	••

n=26.
•Significant (P<0.05); ••Significant (P<0.01).

Table II.11 Performance of pigs fed raw or 'jet-sploded' canola seed (Exp. 4.)

	Processing methods			
	Raw, ground	Jet-Sploded	SEM	Sig.
Weight gain.d^{-1}, g	463	441	15.1	NS
Feed.d^{-1}, g	578	560	12.8	NS
Gain per feed	.807	.789	0.007	NS

n=26.
NS = not significant.

Table II.12. Digestibility coefficients for the five diets. (Exp. 4.)

	1 Control	2 15% raw canola seed	3 15% Jet-sploded canola seed	4 30% raw canola seed	5 30% Jet-sploded canola seed	SEM	Sig.
Protein, %	73.45[a]	79.08[b]	79.32[b]	83.60[b]	80.70[b]	1.38	•
Energy, %	73.04[a]	80.62[b]	80.52[b]	83.74[b]	79.48[b]	1.38	•
Dry Matter, %	76.08[a]	82.50[b]	82.74[b]	85.32[b]	82.43[b]	1.05	•

n = 13.
[a,b]Means with the same superscripts are not significantly different. •Significant ($P<0.05$).

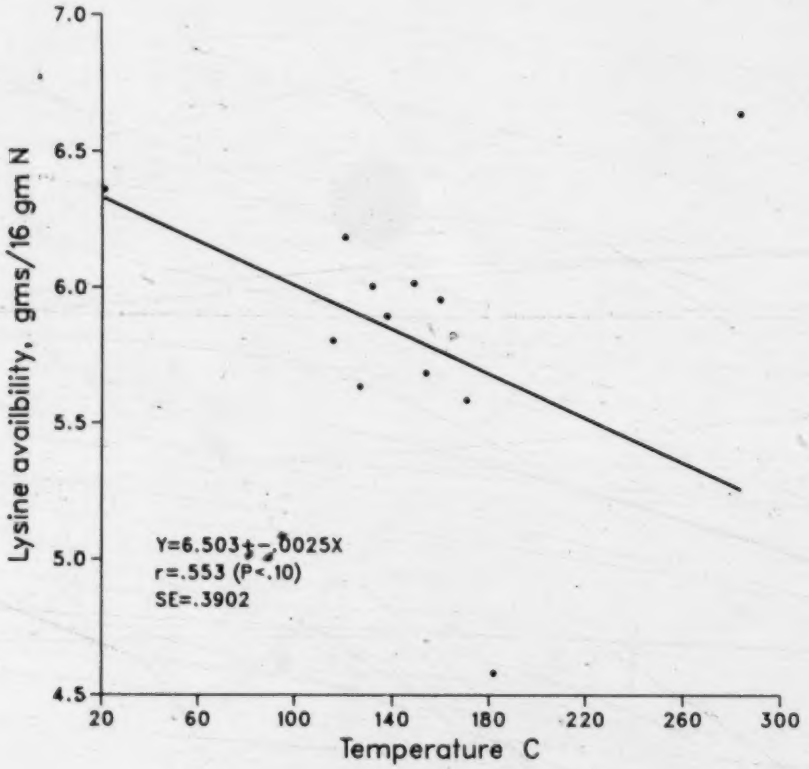

Figure II.1 The effect of the 'Jet-Sploding'™ temperature on the lysine availability from canola seed.

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III. ILEAL AND FECAL ENERGY DIGESTIBILITY COEFFICIENTS OF CANOLA MEAL AND FULL FAT CANOLA SEED FOR SWINE

A. INTRODUCTION

Data on digestibility coefficients of energy and protein of full fat canola seed (CS) are needed if CS is to be used in diet formulation. There have been few studies conducted to determine digestibility coefficients for CS. Bayley (1975) determined a fecal apparent digestible energy (ADE) value of 4.83 and 4.51 Mcal.kg^{-1}D.M. for raw and extruded CS, respectively. The fecal ADE value of frosted CS, when fed to growing pigs at levels of 15% and 30% of the diet, were 3.75 and 4.49 Mcal. kg^{-1}D.M., respectively (Bell and Keith 1986). Salo (1980) determined a fecal ADE value of CS for weanling pigs and reported a value of 4.66 Mcal.kg^{-1}D.M. Thus estimates of the ADE value for CS range from 3.75 to 4.83 Mcal.kg^{-1}D.M. Possible explanations for these differences could be the cultivars of CS used in the tests, the level of CS fed to the pigs, or the age of the pigs on test. Also, the technique used for measuring ADE values of a feedstuff may provide different results.

There are many techniques for determining the apparant digestible energy (ADE) of a feedstuff, such as the total collection method (Bayley 1965), the use of an inert marker such as Dysprosium (Kennelly 1980), and the mobile nylon bag technique (MNBT) (Sauer et al. 1983a,b). There appears to be a discrepancy between ADE values of various feedstuffs depending on which method is used. The total collection method gives larger ADE values than the mobile nylon bag technique (MNBT) with those determined by the inert marker method being intermediate (Sauer et al. 1984a,b).

The objective of this experiment was to determine the ADE value for CS and CM using the inert marker method with ileal and fecal sampling, and the MNBT. Crude protein and dry matter digestibilities were also determined by the inert marker method.

B. MATERIALS AND METHODS

Five Landrace X Yorkshire barrows, weighing an average of 60 kg, were surgically fitted with a simple "T" cannula at the distal ileum, approximately 5 cm from the ileocecal junction, by an adaptation of the method of Sauer et al. (1983a). The pigs were individually housed in stainless steel metabolic crates and allowed to recover after surgery for nearly 3 weeks before the test diets were fed. The environmental temperature was maintained at 22°C throughout the trial. The test diets were formulated to contain 16% crude protein and were supplemented with either canola meal (CM) or full fat canola seed (CS) (B. Campestris cv. tobin). Diet composition is shown in Table III.1. The CM and CS contributed 50% of the dietary protein. The other 50% of the protein in the diet was contributed by casein. The remainder of the diet consisted of cornstarch, sucrose, and sufficient vitamin and minerals to meet or exceed the nutrient requirements of growing pigs, as outlined by the National Academy of Science - National Research Council (1979). The crude protein in casein was considered to be 96% digestible (Leibholz 1982; Just et al. 1983). The energy content of casein, cornstarch, and sucrose was assumed to be 100% digestible (Ewan 1983; Just et al 1983). Both diets were formulated on an as fed basis and were isonitrogenous but not isoenergetic.

Dysprosium chloride ($DyCl_3.6H_2O$) was incorporated into the diets as an inert marker, at a concentration of 10 ppm elemental Dysprosium. After the three week recovery period from surgery, the pigs were allocated to either of the two diets in a 2X2 crossover design with three pigs in group 1 and two pigs in group 2. The pigs were given 800 g of the test diet at 0800 hr and 2000 hr for a ten day adaptation period before collections were made. Fecal samples were collected twice a day for 2 days, then two alternate 24 hour digesta collections (every 2 hr) were made. Digesta samples were collected through a soft plastic tube attached to the external end of the ileal cannula. During collections, the tube was immersed in an ice water bath to stop all microbial action. The samples were frozen immediately after collection. Digesta were pooled daily, for each pig. These two daily samples were later pooled resulting in one digesta sample per pig per treatment. Feces samples were pooled by weight

resulting in one fecal sample per pig per diet. Digesta and feces collected were freeze dried and ground. Samples were analysed for dry matter and crude protein using the techniques outlined by AOAC (1980), and gross energy of combustion as described by Harris (1970). Dysprosium concentration was determined in the fecal, ileal and feed samples using Instrumental Neutron Activation Analysis (INAA) in the SLOWPOKE reactor at the University of Alberta following the proceedure of Kennelly et al. (1980). For each fecal, digesta and feed sample, ileal and fecal digestibility coefficients for energy, crude protein and dry matter were calculated from the relative Dysprosium concentrations in feed, feces and digesta.

Apparent digestible energy values determined in a previous study (Appendix I.) for both full fat canola seed and canola meal using the Mobile Nylon Bag Technique (MNBT), were used as a comparison of the fecal and ileal apparent digestible energy values.

Statistical analysis was performed using a one-way-ANOVA, and orthogonal contrasts of treatment means as described by Steele and Torrie (1980).

C. RESULTS

Ileal and fecal digestible energy values of the canola meal (CM) and the full fat canola seed (CS) are presented in Table III.2. The fecal ADE of the CM and CS were 2.99 Mcal. Kg^{-1}D.M., and 4.71 Mcal.Kg^{-1}D.M., respectively. Ileal ADE values for the CM and CS were 1.88 Mcal.Kg^{-1}D.M. and 4.24 Mcal.Kg^{-1}D.M., respectively. The ADE values for the CM and CS samples derived by the MNBT were intermediate between the two. The results of the orthogonal contrast analysis revealed a difference ($P<0.01$) for both test ingredients, between the ADE values as determined by the ileal or the fecal sampling. There were also differences ($P<0.01$) between the ADE value determined by the MNBT and the fecal ADE and ileal values for the two feedstuffs. Ileal and fecal digestibility coefficients for protein, energy and dry matter are presented in Table III.3. The fecal digestibility coefficients were larger ($P<0.01$) than the ileal digestibility coefficients for both CM and CS.

D. DISCUSSION

This study was conducted to determine the fecal and ileal apparent digestibility coefficient for energy, crude protein and dry matter for CM and CS. The fecal ADE value for CM (2.99 Mcal.Kg^{-1}D.M.) compares favorably with ADE values reported by the NRC (1979), Ewan et al. (1983), and May et al. (1971) which were 2.998, 3.282, and 3.255 Mcal.Kg^{-1}D.M., respectively. The fecal ADE value for CS (4.71 Mcal.Kg^{-1}D.M.) also compares well with ADE values reported by Bayley et al. (1975), Bell et al. (1986), and Salo (1980) which were 4.830, 4.493, and 4.66 Mcal.Kg^{-1}D.M. respectively. ADE values obtained by the MNBT were smaller ($P<0.01$) than fecal ADE values for both feedstuffs. In digestibility studies conducted by de Lange et al (1986), and Sauer et al. (1984a,b), lower ADE values for various feedstuffs were obtained using the MNBT than by conventional methods. They obtained, however, a highly significant correlation between the ADE values derived by the MNBT and those determined by conventional methods. One possible reason for the consistantly low values obtained by the MNBT is that the MNBT does not take into account possible interactions between the feed in the digestive tract of the pig and the test feed in the nylon bag. If products of digestion can flow out of the bag, then it would appear reasonable to assume digestion products from the basal diet or material of endogenous origin could flow into the bag and therefore this technique would underestimate the digestibility of both protein and energy. Nylon bag pore size also may influence the results and the predigestion techniques used in the MNBT may not accurately simulate gastric digestion in the pig.

In a conventional digestibility study the ADE values obtained may also be criticized. There are many methods of evaluating a feed ingredient. One way is to feed a diet consisting entirely of one feed ingredient and adequate levels of vitamins and minerals. The other method involves feeding an entire diet containing other ingredients besides the test ingredient and a basal diet not containing the test ingredient and by difference, determine the digestibility of the test ingredient (Robinson 1965). The former method has the advantage that there is no interaction between the test feed and other ingredients in the diet. Feeding

only one ingredient would give a good estimate of ADE. However, when testing an unpalatable feed ingredient, like canola meal or full fat canola seed, or a less nutritive ingredient such as feed high in fibre or a low protein feed, this second method is less acceptable. In the latter method the interaction between the various components in the diet may alter the digestibility of the test ingredients through the associative effects of feeds (Robinson 1965; and Vik-Mo et al. 1985). The MNBT was developed to test a single ingredient while feeding a basal diet. More research is currently being undertaken to investigate any interaction between the contents of the nylon bag and the feed in the digestive tract of the pig.

The differences between ileal and fecal ADE values may be explained by microbial fermentation in the hind gut of the pig and subsequent absorption of volatile fatty acids (Cranwell 1968). This absorbed energy can account for a considerable increase in energy digestibility. However there is also evidence that microbes synthesize fatty acids in the alimentary tract of the pig (Bayley and Lewis 1965) which alters the fecal digestibility values obtained. Although there is addition of fatty acids, the contribution is small.

Ileal and fecal digestibility coefficients for crude protein, energy, and dry matter for CM and CS were remarkably similar except for the very low (39.9%) energy digestibility for CM from ileal sampling. There were differences ($P<0.01$) between ileal and fecal digestibility for both CM and CS. Fecal digestibilities were larger than ileal digestibilities. Crude protein and energy fecal digestibility coefficients reported by Just et al. (1983) were 72.0% and 65.0%, respectively for double low rapeseed meal. The CS seed diet contained more gross energy than the CM diet and the ileal digestibility coefficient for energy in the CS diet was greater than that of the CM diet. This improved energy digestibility was also reported by Leibbrandt (1975) when fat was added to the pig diets. The source of protein was the same in both CS or CM diets so it was expected that the protein digestibility would be similar.

An important reason for determining the digestibility of the energy and nutrients in a feed ingredient is to assist in ration formulation. The fastest, cheapest, and easiest method of accomplishing this, while giving good repeatable results, is preferable. In many cases

feedstuffs of a non-traditional nature or feed used in third world countries need to be analysed for digestible energy, protein and dry matter. In such circumstances the MNBT should be very attractive.

Table III.1 Composition of diets for digestibility trial.

Ingredients	Canola meal	Full fat canola seed
Canola meal	19.75	—
Canola, raw ground	—	38.00
Casein	8.69	8.69
Cornstarch	57.56	39.31
Sucrose	10.00	10.00
Vit-min. premix†	1.00	1.00
Iodized salt	0.5	0.5
Cal. phosphate	1.5	1.5
Limestone	1.0	1.0
Chemical composition, as fed		
Dry matter, %	89.56	91.15
Crude protein, %	15.99	15.90
Gross energy, $MJ.kg^{-1}$	18.19	21.70

†Premix - each kg of diet contained: 5,000 IU Vitamin A, 500 IU Vitamin D_3, 22 IU Vitamin E, 12 mg Riboflavin, 45 mg Niacin, 25 mg Ca. Pantothenate, 30 μg Vitamin B_{12}, 500 mg Choline Chloride, 120 mg Zn, 12 mg Cu, 150 mg Fe, 12 mg Mn, 20 mg Biotin, 0.3 mg Selenium, 2.5 g ASP 250, 2.5 g Lysine.

Table III.2 Ileal and fecal apparent digestibiilty energy values (ADE) of canola meal and canola seed for swine.

	Apparent Digestible Energy (Mcal.kg^{-1}) DM				
	Fecal	Ileal	MNBT	SEM	Sig.
Canola meal	2.99^{a}	1.88^{b}	2.40^{c}	.093	••
Canola seed	4.71^{a}	4.24^{b}	4.24^{b}	.121	•

$n = 5$

^{a,b,c}Means with the same superscript are not significantly different.
•=significantly different ($P<0.05$), ••=significantly different ($P<0.01$).

Table III.3 Digestibility coefficients of raw canola seed and canola meal determined by the inert marker Dysprosium for growing pigs.

	Canola seed				Canola meal			
	Fecal	Ileal	SEM	Sig.	Fecal	Ileal	SEM	Sig.
Protein, %	86.70	73.30	1.32	**	87.06	73.87	0.89	**
Energy, %	66.60	57.80	1.25	**	63.40	39.90	1.56	**
Dry matter, %	86.80	80.10	0.47	**	90.90	85.10	0.02	**

n=5
**=significantly different ($P<0.01$).

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IV. DISCUSSION

The results of these studies showed that feeding levels of up to 15% raw, full fat canola seed (CS) in the diets of starter pigs did not adversely affect average daily gain (ADG), average daily feed intake (ADF), or gain per unit of feed (GPF). At dietary levels of 30% CS there was a decrease ($P<0.01$) in pig performance. Therefore, the optimum inclusion level of CS in the diet is between 15 and 30%. In one feeding trial the pigs fed the diets containing CS processed at 260°C did not perform as well as pigs fed the diet containing the raw CS or the control diet. This led to the conclusion that the high temperature (260°C) used to process the CS damaged the protein in some way. The 'jet-sploding' process method was evaluated by processing CS at 10 different temperatures ranging from 116°C to 182°C. Digestibility coefficients for protein, energy and dry matter were not significantly reduced with the increasing temperature of processing. However, lysine availability as determined by the di-fluoro-nitro-benzine (DFNB) method (Booth 1971) was reduced as processing temperatures increased. For all subsequent experiments CS 'jet-sploded' at 116°C was used.

In experiment 3 pigs fed raw CS at the 15% level were compared with pigs fed a traditional soybean meal diet and a diet containing 9% canola meal and 6% canola oil. The pigs fed all three diets performed equally well. No improvement was detected in pig performance when 15% 'jet-sploded' CS was used compared to the performance of pigs fed the diets containing 15% raw CS, or the control diet. Increasing the amount of CS in the diet to 30% decreased pig performance whether the seed was in a raw, ground form or 'jet-sploded'. Since 'jet-sploding' did not improve the CS supplemented diets for pigs it is apparently unnecessary to process the seed except by grinding and pelleting. These results are supported by Castell (1977) who fed raw CS to pigs at 15% of the diet and observed no difference in ADF, ADF, or GPF compared to pigs fed a control diet consisting of barley, wheat, and soybean meal (SBM). Salo (1980) detected no significant difference in pig performance when fed diets containing 10% raw ground CS or a control diet based on barley and skim milk.

There was an improvement in energy digestibility coefficients for pigs fed the diet containing 30% CS. Leibbrandt (1975) suggested that the digestibility of ether extract was improved by adding fat to the diet of starter pigs. Because the CS contains approximately 40% oil and was added at 30%, this means that the diet contained 12% oil. At this level of oil inclusion the pigs reduced their feed intake, which tended to negate the improved ether extract digestibility. This is a possible reason why the pigs fed 30% CS had poorer performance.

Ileal and fecal apparent digestible energy (ADE) values for the CS and CM were determined and compared to values published in the literature. In all cases fecal ADE values were higher than ileal ADE values suggesting energy absorption in the hind gut. ADE values determined by the mobile nylon bag technique (MNBT) for the same feeds were intermediate to those determined by ileal or fecal method, as was also reported by Sauer et al. (1984a,b).

ADE values determined by various techniques differ considerably. However, ADE values determined by the MNBT requires less time and expense than ADE values determined by more conventional methods. ADE values obtained by the MNBT correlate well with ADE values determined with conventional studies (de Lange et al. 1986 and Sauer et al. 1984a). The use of the TME_n bioassay also showed a good correlation between the values derived from the adult cockerel and the ADE for the pig. The TME_n bioassay is faster, easier and less expensive than any other method and appeared to predict the ADE value of a feedstuff for swine adequately.

The need for a fast and simple method to determine the apparent digestible energy value of a feedstuff is important for diet formulation. There are often non traditional feedstuffs used in swine diets that do not have any estimate of DE. For feed samples that are not in great supply or must be mailed for analysis, a fast and efficient method of determining ADE with a small sample size is necessary. The TME_n bioassay uses little sample and as values are determined for more feedstuffs a better correlation equation will become available.

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APPENDIX 1 - EVALUATION OF THE MOBILE NYLON BAG TECHNIQUE (MNBT) AND THE TRUE METABOLIZABLE ENERGY (TMEn) ASSAY IN THE COMPARISON OF BIOAVAILABLE ENERGY VALUES OF FEED INGREDIENTS FOR SWINE AND POULTRY

A. INTRODUCTION

The determination of bioavailable energy values of a feedstuff for swine can be an expensive and time consuming task. The most commonly used method of determining digestibility coefficients involve use of an inert marker (Kennelly et al. 1980; Furuichi and Takahashi 1981; Fenton and Fenton 1979) or total fecal collection (Bayley and Summers 1975). Total collection methods require large amounts of the test ingredient, specially designed facilities, and relatively large amounts of feces are collected which must be processed prior to chemical analysis. The use of an inert marker in digestibility studies has advantages over a total collection method but the procedure still involves considerable time in the preparation of feed and the collection of feces for analysis. The Mobile Nylon Bag Technique (MNBT), as described by Sauer et al. (1983a,b), has the advantage over conventional digestibility studies in that the MNBT is rapid, simple, and requires very little sample. Laboratory analysis time is minimized. Also this technique allows digestibility determinations on several samples simultaneously and the digestiblity of individual ingredients of a diet can be determined separately. The majority of the research conducted on the use of the MNBT to determine nutrient digestibilities for swine, has been for protein digestibility in various feedstuffs. Recently Sauer et al. (1984) and de Lange et al. (1986) used the MNBT in the determination of energy digestibility of cereal grains. These researchers reported a significant correlation between the digestible energy (DE) value determined by the MNBT and conventional methods. Therefore, based on the results of these studies it appears that the MNBT is a feasible alternative to conventional methods in determining apparent digestible energy (ADE) value of feedingstuffs for swine.

Sibbald et al. (1983) reported that the ADE values of feedstuffs for swine can be predicted using the True Metabolizable Energy (TME_n) bioassay using adult cockerels. The TME_n assay as described by Sibbald (1982) is a rapid and inexpensive method of determining TME values for a range of feedstuffs for poultry. Sibbald et al. (1983), reported a highly significant correlation between energy values obtained by the TME_n assay with cockerels and the ADE values measured with pigs by use of the inert marker, chromic oxide. In the same study, pooled data of two digestibility trials resulted in a correlation of $r=0.929$.

The objective of our study was to compare ADE values determined for swine by the MNBT and the TME_n values as determined with adult cockerels fed various feedstuffs.

B. MATERIALS AND METHODS

Six barrows weighing approximately 45 kg were surgically cannulated at the duodenum, 5 cm distal from the pyloric sphincter, with a simple T-type cannula. Surgical techniques were conducted as described by Sauer et al. (1983a,b). Pigs were housed individually in stainless steel metabolic crates and allowed to recover for 2.5 weeks after surgery. During the recovery period the pigs were gradually introduced to a 16% crude protein grower diet until they were consuming 2 kg feed per day. Environmental temperature was maintained at 22 °C throughout the trial.

Eighteen feed ingredients were weighed, in approximately 1 gm portions, into labeled 30 mm X 40 mm nylon bags, with a mesh size of 48μm, and sealed with plastic strips. A minimum of 10 bags were prepared for each of the eighteen feed ingredients; twelve of which were samples of full fat canola seed that had been processed at 12 different temperatures using the 'jet sploded' processing method (Appendix 2). The other six samples were corn meals, one alfalfa meal, one canola meal, and one soybean meal. The filled bags were predigested for 4 h in a solution of HCl and pepsin (187 I.U./l) made up to a pH 2.0 at a temperature of 37°C. The bags were put in solution and agitated slowly throughout the incubation period (4h). The bags were squeezed out at the end of the predigestion period and immediately frozen. Prior to insertion into the duodenal cannula, 24 bags were thawed each

day, and warmed in a hot water bath to 37°C. Bags were inserted two per pig, twice daily at 0800 h and 2000 h. These times corresponded to when the pigs were given their twice daily diet of 800 g of a 16% crude protein grower ration. Bags were collected from the feces, scraped and frozen for future analysis. Only those bags which had a rentention time of 96 h or less were kept. The content of each bag was freeze-dried and ground. Proximate analysis was conducted on feed ingredients and contents of the bags after passage through the pig. Dry matter and crude protein were determined using the techniques outlined by AOAC (1980), and gross energy of combustion as described by Harris (1970). Digestibility coefficients were calculated.

Concurrently the same feed ingredients were assayed for TME_n using eight white adult cockerels per feed using the method described by Sibbald (1982). This method involved force feeding a known quantity of each feedstuff into the crop of a fasted bird and collecting all excreta over a 48 h period. An additional eight fasted birds were used to estimate metabolic and endogenous energy losses (Sibbald 1981a,b).

Linear regression analysis was conducted to measure the relationship between ADE and TME_n values (Steel and Torrie 1980).

C. RESULTS

Apparent digestible energy (ADE) values as determined by the MNBT were generally lower than the TME_n values and are summarized in Table V.1. Regression analysis of the mean data resulted in the following linear equation and correlation coefficients (16 d.f.),

$$Y = 0.9308 + 0.65\ X \qquad r = 0.913\ (P<0.01)$$

where Y and X are the fecal ADE and TME_n values (Mcal. Kg^{-1}) of the feed ingredients, respectively. The standard error of the regression coefficient was 0.0925. The correlation coefficient was highly significant and would allow a reasonably accurate estimate of ADE for swine to be made from TME_n values measured with adult cockerels for these feed ingredients (Figure. V.1).

D. DISCUSSION

Sibbald et al. (1983) reported a significant relationship between TME_n and ADE for swine using complete diets. However, the ADE values presented in their work were larger than their TME_n values. The ADE values as determine by MNBT were smaller than the TME_n values. ADE values derived by the MNBT are usually lower than ADE values determined by conventional assays (Sauer 1984).

In digestibility studies conducted by de Lange et al. (1986) and Sauer et al. (1984) lower ADE values for various feedstuffs were derived using the MNBT than by conventional methods. They reported a highly significant correlation between the ADE values determined by MNBT and those determined by conventional methods, ($r=0.99$, de Lange et al.1986 and $r=0.97$, Sauer et al. 1984).

There has been some controversy in the literature as to whether the MNBT and TME_n bioassay represent fully, an ADE value for swine, or a TME_n value for cockerels, respectively. Some factors responsible for differences in energy digestibility between conventionally derived ADE values and MNBT derived ADE values may be that the MNBT does not take into account possible interactions between the feed in the digestive tract of the pig and the test feed in the nylon bag. Any interaction would tend to underestimate both protein and energy digestibility values. Material of endogenous origin or undigested portions of the basal diet could actually enter the nylon bag and decrease the digestibility coefficient. Nylon bag fullness and nylon pore size may also affect this occurance. Also, pre-digestion techniques used in the MNBT may not accurately simulate gastric digestion.

The TME_n bioassay has been criticized by Farrel (1981) and McNab (1984) who suggest that factors such as bird size, age, breed, or day differences affect the amount of endogenous excreta voided by a starved cockerel or one receiving a small quantity of feed and that using starved birds to correct for metabolic and endogenous energy losses is not satisfactory. These criticisms were addressed in reviews by Sibbald (1982 and 1985). Sibbald indicated that increasing the duration of the fast would eliminate any day effect and keeping paired birds as identical as possible would eliminate the bird effect on endogenous secretions.

Correcting the TME_n value to zero nitrogen balance eliminates the possible effect of nitrogen in the urine from catabolism in the starved birds and provides a good and rapid measurement of TME_n values for a variety of feedstuffs. One modification of the bioassay could be the supplementation of glucose to the 'starved' birds but this proposal only indicates minor changes which Sibbald (1985) does not feel to be absolutely necessary.

In view of the support given to each of the assay methods used in this study and the highly significant correlation between the ADE value for swine and the TME_n value for adult cockerel, it would appear that the rapid TME_n bioassay could be used to predict the ADE value of a feedstuff for swine.

In order to determine if our regression equation does indeed predict the ADE of a feedstuff for swine, inserted into the equation, ($Y = .9308 + .65\ X$), were TME_n values for certain feedstuffs obtained from published results by Sibbald (1976, 1977a, 1977b, 1977c) and our own results. Calculated ADE values for the feedstuffs are presented in Table V.2. The feedstuffs used in the comparison were: wheat (hard), oats, soybean meal (49% crude protein), wheat shorts, alfalfa meal (17%-18 % crude protein), barley, rapeseed meal, full fat canola seed, wheat bran, and fish meal (63% crude protein). We compared our predicted ADE values and those ADE values published by NRC (1979) for swine. Results of a one-way-ANOVA showed no significant differences between the predicted and observed ADE values for these feed ingredients. For many feedingstuffs there are no or few TME_n values published which is a limiting factor in the use of TME_n to accurately predict the ADE value for swine of many feedstuffs. However this preliminary study indicated that the TME_n bioassay may be a quick and accurate method of predicting the ADE value of feedstuffs for swine.

Table V.1 Comparisons between true metabolizable energy (TMEn) bioassay values and apparent digestible energy (ADE) values as determined by the mobile nylon bag technique (MNBT).

Ingredients	MNBT-ADE Mcal.kg^{-1}. DM	TMEn Mcal.kg^{-1}. DM
Canola meal	2.40	2.07
Canola seed (raw)	4.24	4.76
Canola seed†		
116°C	4.45	5.24
121°C	4.30	5.25
127°C	4.19	5.26
132°C	4.36	5.12
138°C	3.99	4.91
149°C	4.19	5.25
154°C	3.39	3.97
160°C	4.14	5.10
171°C	4.13	5.14
182°C	4.77	5.08
260°C	3.54	4.54
Alfalfa meal	1.08	1.22
Soybean meal	3.21	2.73
Corn meal A	3.52	3.68
Corn meal D	3.86	3.96
Corn meal F	3.76	3.90

†Temperatures correspond to "Jet-Sploding" processing method.

Table V.2 Predicted and actual ADE values for swine using TMEn values from adult cockerels.

Ingredients	Fecal ADE (Mcal.kg^{-1}) DM		TMEn (Mcal.kg^{-1}) DM
	Predicted†	NRC	
Wheat (hard)	3.48	3.48	3.92
Oats	3.25	2.86	3.58
Soybean meal (49%)	3.03	3.35	3.23
Wheat shorts	2.81	3.17	2.90
Alfalfa meal (17-18%)	1.92	2.50	1.52
Barley	3.14	3.08	3.40
Rapeseed meal	2.43	2.99	2.31
Canola seed	4.26	4.24‡	5.13
Wheat bran	2.11	2.51	1.82
Fish meal (63%)	2.88	3.08	3.00

‡Observed ADE value from Chapter III.
†Predicted using the regression equation: $Y = .9308 + .65X$
Where Y = predicted ADE: X = TMEn value.

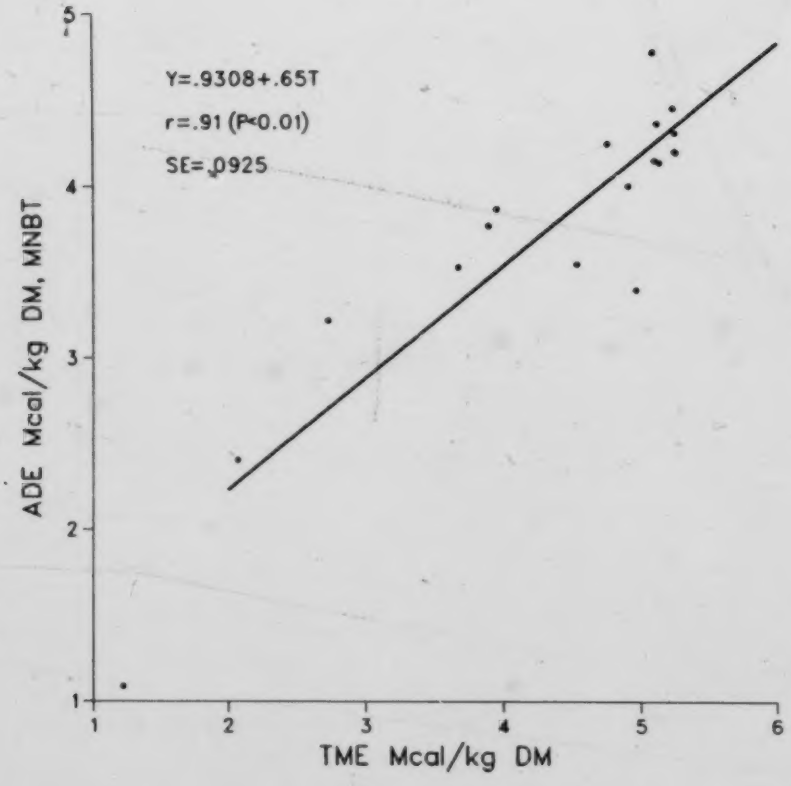

Figure V.1 Relationship between True Metabolizable Energy Values (TMEn) and Apparent Digestible Energy (ADE) values for a variety of feedstuffs.

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APPENDIX 2 - THE 'JET-SPLODING™ PROCESSING METHOD FOR CANOLA SEED

The canola seed, (B. Campestris cv. tobin) used in experiments 1 and 4, was processed using the 'Jet-Sploder'™. This technique involved subjecting the canola seed (CS) to superheated air for a predetermined time, followed by passage through a roller mill (Morrill 1984). Whole full fat CS was fed by gravity into the heat exchanger (Figure VI.1). Air heated to about 316°C was pumped through jets into the exchanger where the CS was quickly heated and transported through the unit. After the desired time in the heat exchanger the CS was fed through the rollers. As the CS resides in the heat exchanger the natural moisture within the seed gets superheated and pressurizes, rupturing the cells. Control of the air flow system and a variable speed seed feeder ahead of the rolls resulted in the desired residence time for the CS in the heat exchanger and thus the desired heating time. Different lengths of retention time are required for different grains in order to get the optimum seed core temperature.

On the recommendation of the California Pellet Mill the first batch of CS was retained in the heat exchanger for 60 to 90 seconds. The estimated seed core temperature reached 260°C.

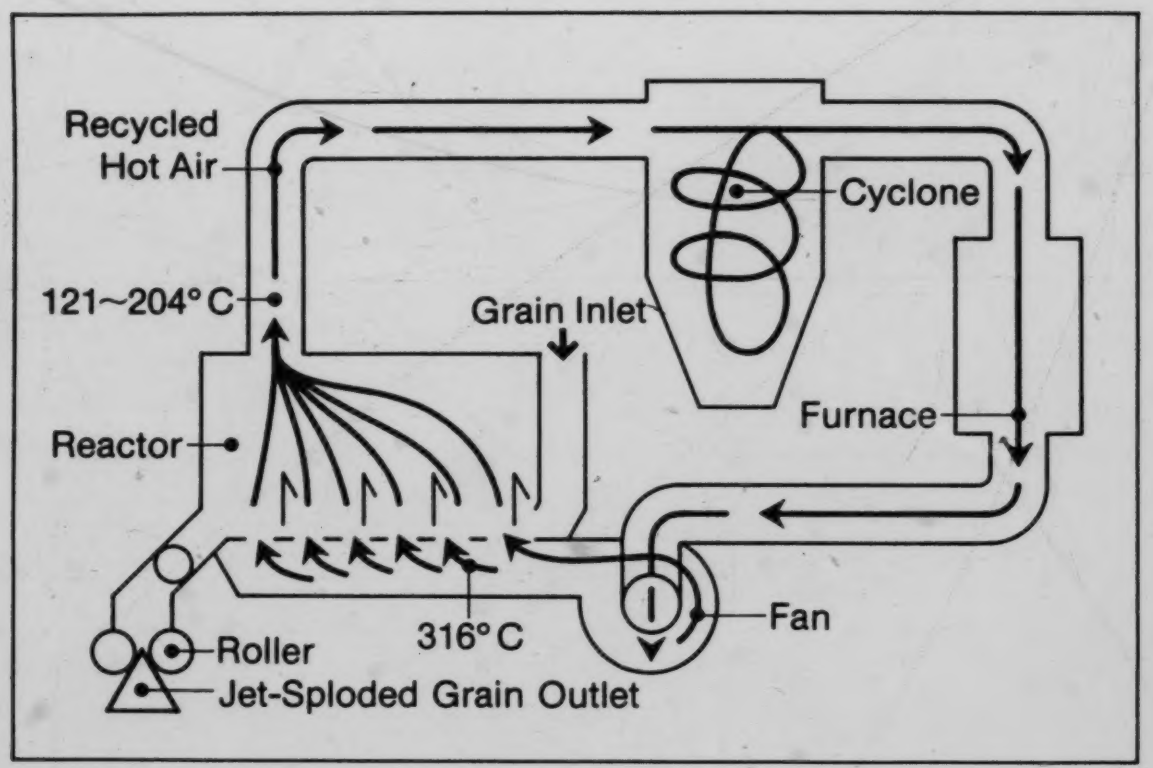

Figure VI.1 Diagrammatic representation of the 'Jet-Sploder'™.

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